Report No. 54

REVIEW OF ENVIRONMENTAL INVESTIGATIONS AT JOHNSON CONTROLS' FOWLERVILLE, MICHIGAN, SITE

January 9, 2002

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Summary

Wastes from the Johnson Controls Inc. (JCI) site in Fowlerville, Michigan, have contaminated soil and ground water at the plant and sediment in the Red Cedar River. A plume of ground water contaminated by high concentrations of the solvent trichloroethylene (TCE) and its breakdown products forms an east-west band across the southern portion of the plant and discharges into the river. River sediment contains elevated levels of polychlorinated biphenyls (PCBs), chromium, and other chemicals adjacent to the plant and for a distance of a mile or more downstream.

It is now more than twenty years since ground-water contamination was discovered beneath the site and PCBs were discovered in the river. Yet no long-term remedy has yet been selected, let alone implemented. JCI has studied the site pursuant to USEPA requirements, but we have identified several serious deficiencies in their investigation and evaluation.

Johnson Controls did not properly evaluate sediment contamination in the Red Cedar River. JCI compared the sediment data to three decreasingly stringent criteria, erroneously concluding that the least stringent set (which JCI itself developed) was most applicable to the site data. All three comparisons show that there is a problem in the river, yet JCI downplayed this result and concluded that there is little present-day impact on the Red Cedar River from the site. Specific problems with the sediment evaluation include:

- Polychlorinated biphenyls were not detected in any upstream samples, but were present in the sediment nearby and downstream of the site at levels above USEPA standards. JCI never stated the obvious conclusion that the plant has contaminated the river with PCBs.

- Johnson Controls dismissed the USEPA standards for river sediments, arguing that they are too conservative to use to identify site-related contamination. USEPA's Ecological Data Quality Levels are tied to protecting river ecology, not distinguishing background concentrations from site-derived contamination. The presence of background contamination is no reason to ignore these standards.

- Johnson Controls defined a statistical criterion for identifying site-related contamination and then dismissed it, arguing that this criterion too is overly conservative. JCI's statistical analysis had severe shortcomings. The upstream river samples were too few and samples that had been collected years apart were improperly combined into a single

data set. Even if it had been properly applied, JCI's statistical test is ill-suited to determining whether its plant has contaminated the river.

- Johnson Controls argued that the best way to distinguish site-related contamination is to consider samples to be contaminated only if they have higher concentrations than *all* background samples. This criterion is distinctly non-conservative and can erroneously screen out contaminated samples. Moreover, JCI chose its maximum background concentrations from a data set in which roughly two thirds of the samples were collected six years earlier than the downstream samples. It is probable that upstream of the plant the river is being cleaned up and contamination is declining, making it improper to use old measurements to evaluate current background conditions in the river.

While river conditions downstream of the plant have improved over time, sediment remains contaminated 15 years after the plant stopped operating. This problem requires further action. JCI should implement a comprehensive program to control contaminated runoff and discharge from the site. This program should include clean-up of on-site ground water, surface water, sludge, contaminated soils, and storm water.

Because most of the site is situated on the flood plain of the Red Cedar River, remedial measures must be put into place to prevent contaminated soil from washing into the river during large-scale floods. This might include either excavation or capping of appropriate areas. Special attention also needs to be given to PCBs that are dissolved in kerosene.

Decisions about whether and how to clean up contaminated sediments in the river are likely to be based on a risk assessment. Because risk assessment is a process that involves much judgement, it is important to avoid the appearance and the reality of bias. All risk assessments at this site should be conducted by USEPA personnel rather than JCI's consultants.

As with the river sediments, JCI's discussion of arsenic in soil is based on a flawed statistical analysis of background contamination. The arsenic problem requires further investigation to determine what kind of clean-up is necessary.

We have also identified serious problems in JCI's evaluation of ground-water contamination by TCE and other industrial solvents:

- Johnson Controls concluded after Phase II that the plume of TCE-contaminated ground water might originate off site — that is, that some other company may have caused the problem. Although a primary objective of the Phase III investigation was to better define the source areas of the TCE plume, the Phase III report does not identify the source areas.

- The Phase III RFI report misleadingly depicts the TCE plume in ways that minimize its seriousness. The plume is depicted as three hotspots, with concentration contours that suggest that little contamination reaches the river. However, there is little support for this interpretation. The existing data are too sparse to fully determine the plume configuration, and they support an interpretation in which a continuous contaminant plume with a central spine of high concentrations reaches all the way to the river at least as well as they support JCI's interpretation.

- JCI wrongly claims that the TCE plume "is not expected to persist at significant concentrations because of its demonstrated attenuation away from source areas." In fact, the plume is not cleaning itself up. Although it is true that TCE is degrading to some extent in portions of the plume, the process does not go to completion. TCE and its daughter products remain in all sectors of the plume at concentrations hundreds to thousands of times above standards.

- In the western portion of the plume, where TCE degradation appears to be most advanced because no TCE was detected, there is still 8,370 ppb of DCE and 1700 ppb of vinyl chloride, two degradation products of TCE. Vinyl chloride is more toxic than TCE.

- The number of wells is insufficient to define the vertical configuration of the TCE plume and to determine whether contamination may be migrating under the river.

Despite the data gaps that exist, it is still possible to consider different remedial options and define required future work. Additional work will be needed to determine TCE source areas and the depth of the VOC plume. Additional permanent wells are recommended both on-site, along the length of the plume, and off-site east of the plant boundary and on the west side of the river. Several of these will need to sample water from the deep zone.

Under present conditions it is clear that natural attenuation does not fully degrade the plume before it moves off site. Therefore, natural attenuation is not viable as a stand-alone remedy. Also, the biological and chemical processes that are partially degrading the TCE are insufficiently understood to consider natural attenuation even as a component of an engineered remedy.

After two decades of study, action to contain the solvent plume is overdue. Several cost-effective methods, including well-based hydraulic containment and zero-valence treatment walls, are available to do this. If additional investigation identifies strong TCE source areas, then containment, treatment, or removal measures at the source area should be required.

CONTENTS

1. Introduction

The purpose of this report is to evaluate the RCRA Facility Investigation (RFI) performed by Johnson Controls, Inc. (JCI) at the former Stanley Tools facility in Fowlerville, Michigan. The facility was previously owned by Hoover Universal, Inc., which was bought by JCI in 1985. The RFI was conducted under a Consent Order negotiated between Stanley Tools and USEPA in 1988. Remedy selection will be covered by a future Consent Order currently under negotiation. Because this is a complex site with a long history, this report will not attempt to cover all issues relating to the site, but will focus on those most important to long-term remedy selection.

1.1 Reports reviewed

The RFI provides the primary technical basis for selecting a long-term remedy for the site. Our evaluation focuses on the adequacy of the data collected to date, the quality of interpretation and analysis, and implications for cleaning up the site.

The key documents in our review are the October 2001 *Summary Report, RCRA Facility Investigation - Task 10* and the December 2000 *Phase III RCRA Facility Investigation Task 10* report, both prepared by JCI's consultant, URS. The Summary Report, which is currently under review by USEPA, provides an overview of investigations at the site. The Phase III Report contains the results and analysis of recent additional investigations required by USEPA Region 5 on contaminant distributions and source areas. Two other important documents are the 1991 *Phase I RCRA Facility Investigation Task 10* report and the 1994 draft *Phase II RCRA Facility Investigation Task 10* report, both prepared by Dames & Moore, consultant to Stanley Tools.

1.2 Organization of this report

Section 2 of this report briefly summarizes the background and history of the site, including an overview of past investigations. Section 3 describes the physical setting of the JCI facility. Sections 4, 5 and 6 discuss the findings of JCI's most recent investigation and identify deficiencies in JCI's analysis of the data. Section 7 discusses possible remedies for the contamination and presents some recommendations for the next phase of work.

2. Background and history

Johnson Controls' Fowlerville site has a long and complex history of ownership, operations, and regulatory oversight, which is briefly summarized in this section. More detailed information is found in the RFI reports.

2.1 Ownership

The JCI facility is located at 425 Frank Street in Fowlerville, Michigan. Beginning in 1949, the 14-acre site housed a company which cast zinc-based automotive and plumbing parts, some of which were electroplated. In the late 1960s, the plant was bought by Hoover Ball and Bearing Company, later called Hoover Universal Incorporated, Die Cast Division. In 1980, Stanley Tools bought the plant and manufactured plated, die-cast hand tools until 1985. Through its 1985 purchase of Hoover Universal, JCI assumed Hoover Universal's liability for the site. In 1996, JCI entered an agreement to assume total ownership and responsibility for the site [Kolesar, 1996].

2.2 Wastes and discharges

The Red Cedar River is the JCI plant's western boundary. A variety of chemical wastes from metal plating has been treated at the site and discharged into the river since the 1950s. These chemicals include cyanide, chromic acid, and various metals. Production wastes were treated in tanks and ponds to reduce toxicity or separate solids, and the treated wastes were discharged into ditches or pipes that led into the river. Kerosene (used to clean molds) and oils were also separated from aqueous wastes in ponds. In all, there were at least five unlined treatment or settling ponds. Accumulated sludges from the ponds were spread or buried on site.

In 1970, the facility constructed a wastewater treatment plant which included four additional ponds. Sludge from these new ponds was chemically treated and buried on site. The plant also had several storm sewer and tile drain systems that discharged metal-contaminated water into the river.

2.3 Discharge permits

The plant's industrial wastewater discharges into the river have been regulated since the early years of operation. In 1953, the Michigan Water Resources Commission limited the volume of the plant's electroplating process wastewater to 20,000 gallons per minute and required that concentrations of cyanide and various metals be no more than to 2 parts per million (ppm). Beginning in the 1970s, the Clean Water Act's permit program regulated the discharges and required that the average concentrations be lowered by 20 to 90 percent.

2.4 Investigations

Table 3-1 of the Phase II report contains a list of reports generated by past investigations and studies at the site. This is reproduced in this report as Appendix A. More than two dozen documents are listed; many are dated prior to 1980.

Industrial wastewater surveys and monitoring of discharges into the Red Cedar River began in the early 1950s, under state regulatory programs. In the late 1970s, a system of wells was installed to monitor ground-water contamination. Initially, the wells were tested for metals and cyanide associated with casting and plating operations. The Michigan Department of Natural Resources, the predecessor agency of the Department of Environmental Quality (MDEQ), studied suspended sediment in the Red Cedar river in 1978. It found high concentrations of cyanide, metals, and PCBs. In 1980, Stanley Tools notified USEPA that it handled hazardous waste at the plant, and filed for a Resource Conservation and Recovery Act (RCRA) Part A permit. Detection of ground-water contamination triggered RCRA requirements for an on-going ground-water quality assessment.

In 1988, USEPA and Stanley Tools signed a Consent Order that required Stanley to conduct a RCRA Facility Investigation (RFI). In 1990 and 1991, Stanley Tools conducted a Phase I RFI. The main purpose of Phase I was to characterize waste and waste handling units on site ("solid waste management units", or SWMUs) and to determine the extent of soil, ground-water, and surface-water contamination arising from them.

Phase I identified 12 SWMUs and two additional "areas of concern." These are listed in Table 1. Figure 1 is a map reproduced from the Phase III report that shows the locations of the units and areas of concern.

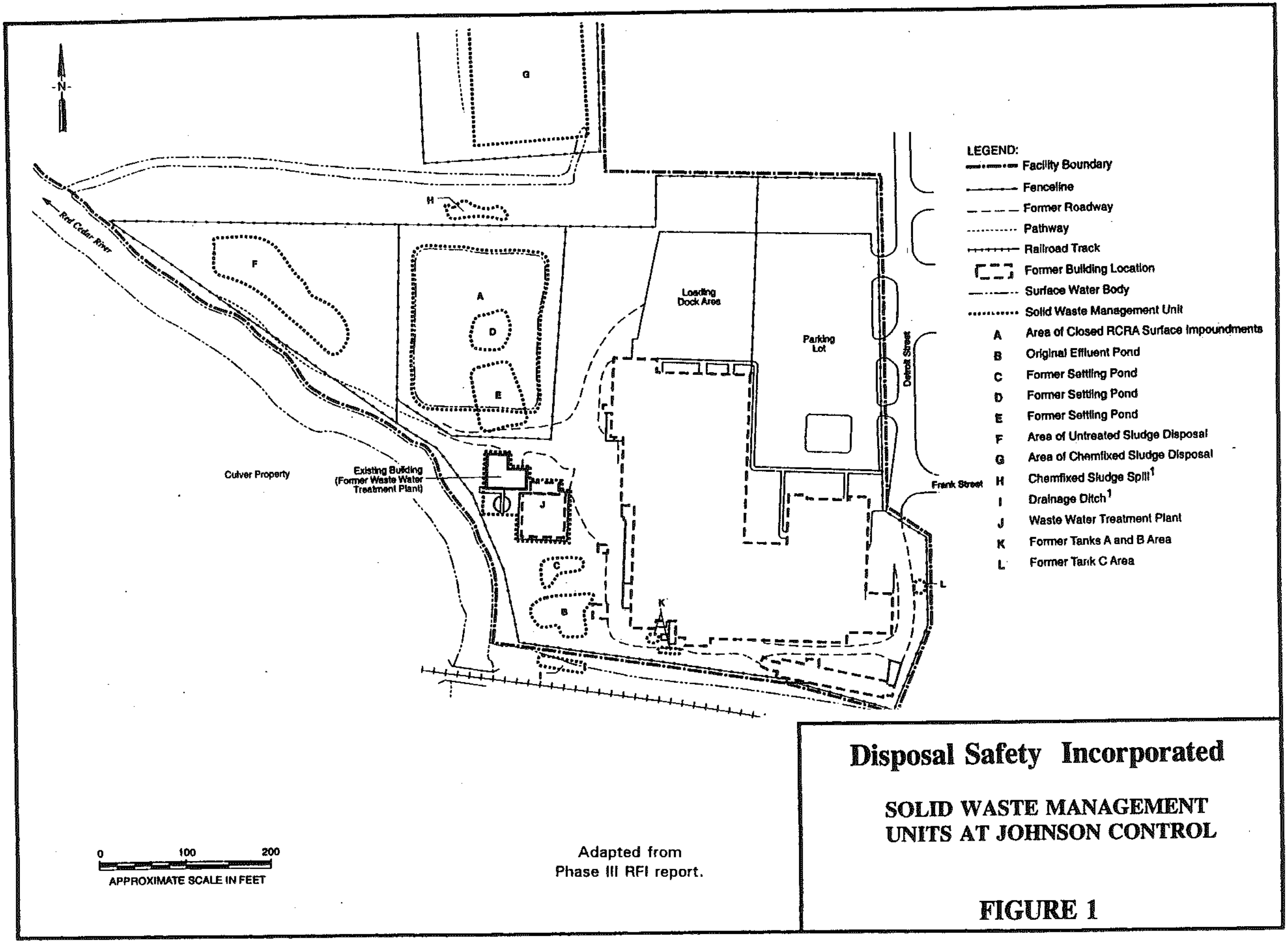
Table 1

Solid Waste Management Units and Areas of Concern

Unit A: Former RCRA Surface Impoundment Area
Unit B: Original Effluent Pond
Unit C: Former Kerosene Settling Pond
Unit D: Former Kerosene Settling Pond
Unit E: Former Kerosene Settling Pond
Unit F: Untreated Sludge Disposal Area
Unit G: Chemfixed Sludge Disposal Area
Unit H: Sludge Spill
Unit I: Southern Drainage Ditch
Unit J: Wastewater Treatment Plant
Unit K: Former Underground Storage Tank Area
Unit L: Former Underground Storage Tank Area
Area of Concern 1: Chromium Recovery Unit
Area of Concern 2: Product Release Area

In 1994, Stanley Tools conducted the Phase II investigation, designed to better delineate the extent of contaminant releases from specific SWMUs and the overall distribution of soil and ground-water contamination. During this investigation, numerous ground water, soil, sediment, and sludge samples were collected from the plant property, the Red Cedar River, and drainage ditches connecting the two.

In mid-2000, JCI conducted the Phase III RFI investigation to better delineate sediment and ground-water contamination. The sediment investigation evaluated the distribution of contaminants in river and ditch sediments that could degrade the ecology of the river. For this purpose, the Phase III report used USEPA Ecological Data Quality Levels (EDQLs), as well as other criteria developed by JCI, and stressed that the evaluation was for "screening purposes," not to establish clean-up goals. The ground-water investigation focused on the most serious



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SOLID WASTE MANAGEMENT UNITS AT JOHNSON CONTROL

FIGURE 1

ground-water contaminant, trichloroethylene (TCE), a widely used industrial solvent. The objective was to better define the geometry of the TCE plume and identify its source area.

In July, 2001, USEPA asked JCI for an additional report to summarize and analyze the three phases of work. Although the Summary Report does not contain any new data, it does contain some new data synthesis and conclusions.

2.5 Wastes

The Phase I and II investigations identified a wide range of chemicals and waste components that exist in the various media at the site. The principal contaminants at the site are listed in Table 2.

Table 2

Principal Contaminants

Metals and semi-metals:
tri- and hexavalent chromium, cadmium, mercury, copper, lead, nickel, and arsenic
Petroleum products/constituents:
bunker C oil, kerosene, fuel oil, xylene, and benzene
Cyanide
Polychlorinated biphenyls (PCBs)
Volatile organic compounds (VOCs):
trichloroethylene (TCE), 1,2-dichloroethene (DCE), vinyl chloride, chlorobenzene, methylene chloride, and dichloroethane (DCA)

2.6 Soil and ground-water contamination identified in Phase II

The Phase II report concluded that numerous operations and waste materials contaminated the site. Sludges in, or originating from, certain SWMUs were probable sources of soil, ground water, and sediment contamination. Some of these sludges contained concentrated metallic and organic contaminants. For example, the 1.2-foot-thick layer of sludge from the Original Effluent Pond (SWMU B), located in the southern portion of the site, contained concentrated zinc, chromium, copper, nickel, phthalates (plasticizers), cyanide, petroleum hydrocarbons, TCE, DCE, and PCBs. Sludge in the Kerosene Settling Pond (SWMU C), contained the same metals and also phthalates, petroleum hydrocarbons, dioxin, and PCBs. Soils associated with these units show a related pattern of contamination.

Sampling in 99 borings located in a grid pattern across much of the site showed that soil contamination is widespread. Primary soil contaminants include metals, PCBs, petroleum hydrocarbons, phthalates, and polycyclic aromatic hydrocarbons. Contamination was also found in samples collected along the eastern bank of the Red Cedar River. With the exception of some obvious hot spots, the soil contamination wasn't easily tied to specific SWMUs. Much of the shallow ground water beneath the plant property contains elevated levels of arsenic, nickel, and zinc, but once again the pattern of contamination was not strongly correlated with specific SWMU locations.

Analysis for volatile organic compounds revealed that the southern portion of the site was highly contaminated with TCE, DCE, vinyl chloride, methylene chloride, and trichlorobenzene. These are all chemical solvents or their breakdown products. Maximum concentrations were in the thousands of ppb for TCE, DCE, and vinyl chloride. The highest concentrations occurred at the eastern property boundary, near a former underground tank that, according to JCI, stored fuel. The monitoring well network was not dense enough to yield a clear picture of the plume geometry or source areas. Despite this, JCI concluded that the source of the contamination could be off site.

The Phase II report also identified releases from a pipeline (identified as "Area of Concern #2") as a probable source of PCBs and petroleum hydrocarbons in the soil and ground water in the area.

2.7 Past remediation

Stanley Tools carried out two interim remedial measures in 1994 and 1995. Waste material was removed from sludge handling areas and a drainage ditch (SWMUs F,G,H, and I) and drums were removed from a burial area near SWMU B. Also, in 2001, JCI conducted an interim stabilization to stop the seepage of oil from the ground and abandoned pipes into the Red Cedar River.

3. Physical setting

3.1 Geography and the river

Fowlerville overlies a glacial moraine with relatively poor drainage. The terrain is hummocky (irregular small hills) and marshy. The major geographic feature in the area is the Red Cedar River; this is a medium-sized river that flows north into Michigan's largest river, the Grand River, at Lansing. The plant is located on the western side of Fowlerville, and most of its acreage is in the floodplain of the river.

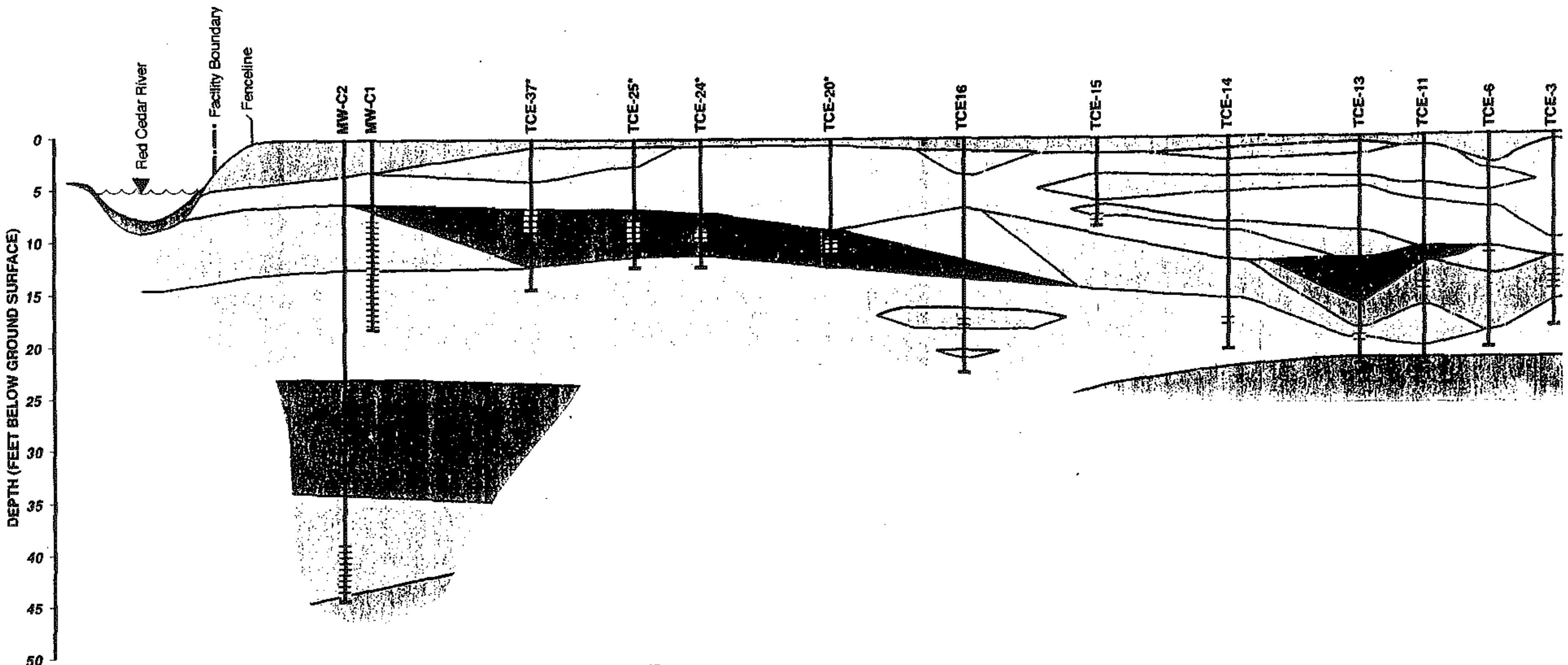
The western boundary of the site is the east bank of the river; the Chesapeake and Ohio Railway is the southern boundary. Topography at the site is nearly flat, with a slight westerly slope towards the river. Two drainage ditches in the northern and southern portions of the site conveyed wastewater and storm water from the plant into the river. In times past, two or more pipes from the plant also discharged directly into the river.

The JCI facility is located in a mixed-use area with residential, commercial, and industrial properties. The closest residences are approximately 300 feet away. The Phase II report lists several water supply wells within 3000 feet of the plant, including three public supply wells approximately 2000 feet northwest of the plant. A municipal sewage treatment plant is located approximately one-half mile north of the plant.

3.2 Geology

Figure 2, reproduced from the Phase III RFI report, shows a cross section of the geology across the site, oriented along an east-west direction.

The site is underlain by three to six feet of surficial soils atop thirty-five to forty-five feet of glacial sediments. Sandstone and limestone form the bulk of the underlying bedrock. The surficial soils consist of the Linwood organic-rich muck near the river, the Berville loam across much of the rest of the site, and silty-sand fill in areas associated with the SWMUs near the river. As might be expected, the fill has higher hydraulic conductivity, lower organic content and lower porosity than the natural soils.



SCALE IN FEET
VERTICAL EXAGGERATION = 4x

LEGEND:

- Riverbed Sediment
- Organic Silt and Silty Loam
- Clay, Silty Clay, Sandy Clay
- Poorly-Graded Sand or Gravelly Sand (Little or No Fines)
- Well-Graded Sand or Gravelly Sand (Little or No Fines)
- Silty Sand, Sand-Silt Mixture
- Alternating Silty Sand and Clayey Sand
- Bedrock
- MW-C1 Monitoring Well/Temporary Piezometer Location and Number
- Screened Interval

NOTES:
- Ground surface topography depicted as flat between TCE-3 and MW-C2 has not been surveyed but has an approximate maximum relief of 3 to 5 feet in that interval.
- The depth and thickness of the strata indicated on the subsurface section were obtained by interpolating between test borings. Information on actual conditions exists only at the locations of the test borings and it is possible that the conditions may vary from those indicated.
- Asterick (*) indicates that boring has been projected 10 feet south of actual location to be included on cross section.
- For location of cross section, see Figure 4-1.

Adapted from
Phase III RFI report.

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GEOLOGIC CROSS SECTION AT THE JOHNSON CONTROLS SITE

FIGURE 2

The Phase II report describes the glacial sediment as being divided into two zones: a 10-to-20 foot thick lodgement till (sandy clay/silt) overlain by a 20-to-30 foot thick zone of intermixed outwash and ablation till (predominantly silty fine sand or silty clay). The uppermost fine sand layer, which appears to have the greatest ability to transmit significant amounts of ground water, is thickest in the central portion of the site.

3.3 Hydrogeology

According to the Phase II and Phase III RFI reports, ground water in the sediments and underlying bedrock form a single aquifer system which is locally divided into sub-aquifers. Ground water flows most readily in two zones: an upper sedimentary horizon consisting of a group of fine sand beds, and a lower layer consisting of sandstone and shale bedrock overlain with dense, silty sand. The upper fine sand layers tend to thin with distance from the river and are interspersed with silty/clayey layers which act as semi-confining beds. Near the river, the semi-confining layers are largely absent. The Phase II report refers to the zone comprising the upper sandy layers and the semi-confining layers as the "upper facies," and the lower silty sand layer as the "lower facies." These relationships can be seen in Figure 2.

Slug tests were conducted in wells screened in the upper sandy zone. This type of aquifer test is not highly precise but provides a useful qualitative description. These tests yielded moderate hydraulic conductivities that ranged from 2.4×10^{-4} to 4.8×10^{-3} cm/sec. Conductivity tended to decrease with distance from the river; this is consistent with a thinning of the fine sand layer and progressively higher silt and clay content of the sediment. Laboratory tests of the silty/clayey material from the semi-confining layers yielded low hydraulic conductivities of 10^{-7} cm/sec or less. Tests on the upper portion of the lower silty sand yielded hydraulic conductivities of 9.8×10^{-5} to 7.4×10^{-4} cm/sec, approximately an order of magnitude less than the upper sandy unit. Deep wells screened into the bedrock and the sediments immediately above it yielded hydraulic conductivities that ranged from 10^{-4} to 10^{-3} cm/sec.

3.4 Flow and transport

Beneath the site, the water table is approximately five feet below the surface. The ground-water gradient beneath the site varies with location and, to some extent, depth. In general, ground water flows from east to west, towards the boundary formed by the Red Cedar

River. In the southern portion of the site, the gradient in the shallow ground water steepens immediately adjacent to the river (within one to two hundred feet). In the northern portion of the site, this steepening is reduced or absent, and the gradient (hence the discharge) appears to vary with river stage. In the deeper (lower facies) ground water, the flow pattern resembles that in the shallow zone, but the gradient is less pronounced. A slight upward gradient between the deeper and shallower horizons indicates that ground water upwells prior to discharge into the river.

Based on three shallow monitoring wells on the west side of the river, the Phase II report concluded that ground water on that side flows east and discharges into the Red Cedar River; thus the river would act as a barrier to westward contaminant movement. But because there are no deep monitoring wells on the west side of the river, this conclusion has not been verified for flow in the deeper zone.

3.5 River quality

Beginning in 1964, the predecessor agency of the Michigan Department of Environmental Quality, the Department of Natural Resources, conducted a series of biological investigations of the effect of the Stanley site on the Red Cedar River near Fowlerville. In the 1960s, the agency concluded that discharges from the plant completely eradicated sensitive species for as far as 4.5 miles downstream. However, the Phase II report states that later surveys, performed in 1976 and 1991, point to improvements in river quality that may have resulted from the installation of a wastewater treatment plant at the plant in 1969.

4. Phase III ground-water investigation

JCI concluded in its Phase II report that the plume of TCE-contaminated ground water might originate off site — implying that some other company may have caused the problem. A primary objective of the Phase III RFI investigation was to better define the geometry and the source areas of the contaminant plume caused by TCE and its break-down products. The investigation included resampling of 21 existing monitoring wells, along with the collection of additional soil and ground water data at 30 new locations across the southern portion of the site using temporary wells.

Another important Phase III objective was to investigate sediment contaminant levels in the Red Cedar River and the drainage ditches connecting it to the plant and to conduct a preliminary assessment of the ecological risk to the river.

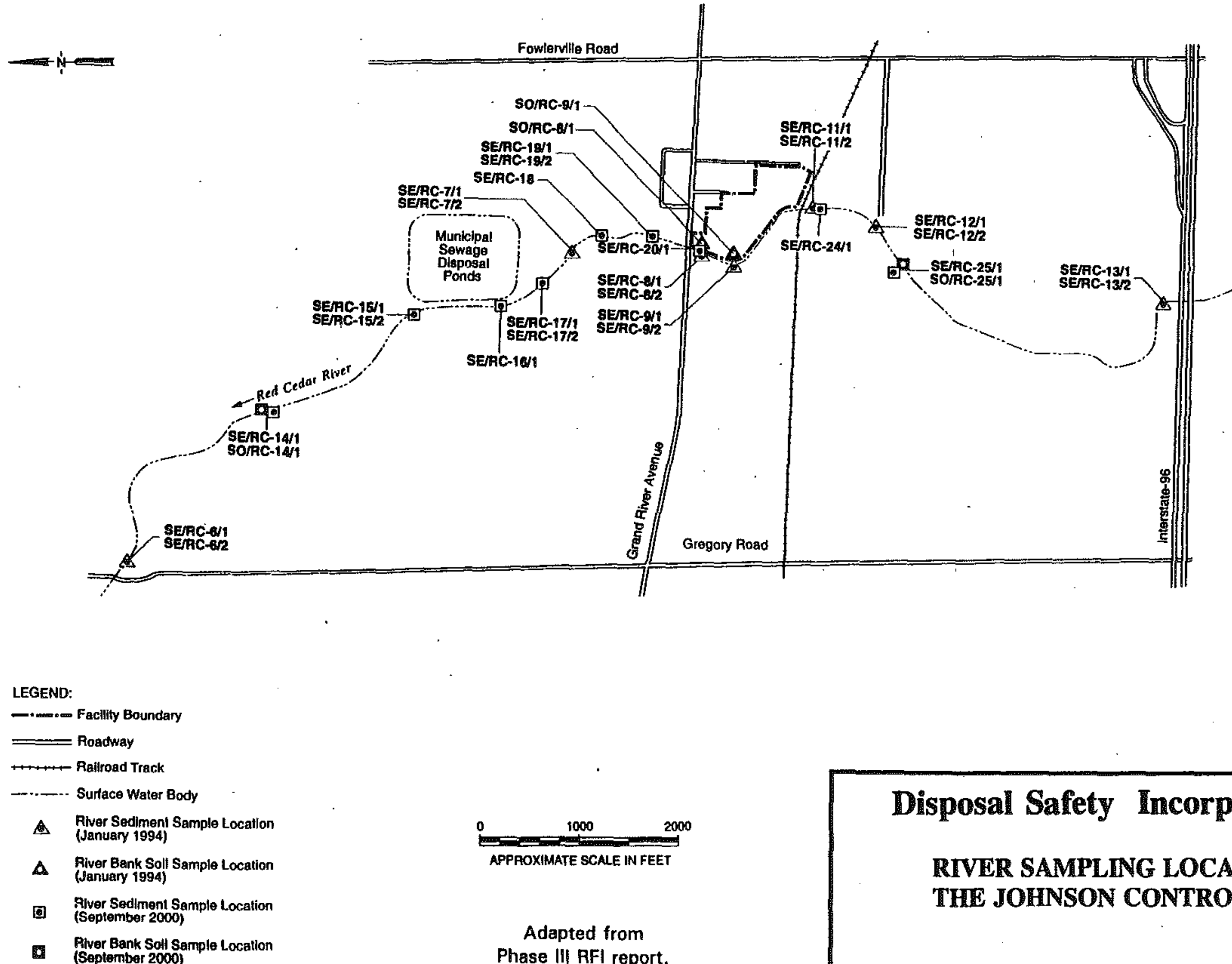
4.1 Phase III TCE investigation findings

Phase III field work occurred between May and September of 2000. During the sampling of monitoring wells MW-C1 and MW-C3 (near the former settling pond), a layer of what resembled weathered (that is, old) kerosene up to two feet thick was found floating atop the water in the wells. This petroleum substance also contained 630 ppm of PCB.

JCI's interpretation of the horizontal and vertical distribution of TCE, its breakdown products (DCE, vinyl chloride) and other solvents is shown in Figures 3 and 4, reproduced from the Phase III RFI report. The plume is depicted as containing at least three large "hot spots" — areas of shallow ground-water contamination in which VOC concentrations exceed 10,000 ppb — along the flow path of the plume. The hottest is the central one, in which VOC concentrations total nearly 18,000 ppb. The three hot spots are embedded in what appears to be a roughly continuous spine of high concentrations along the longitudinal axis of the plume.

Comparison of JCI's plume map with the measurements it is based on reveals important features, many of which are downplayed or ignored entirely by JCI:

- The plume extends without interruption from the eastern boundary to the western boundary of the site.
- Ground water contaminated with volatile organic compounds (VOCs) discharges into the river.
- Because the sediments are complex and heterogeneous and the data are sparse, the geometry of the zone of greatest concentration is not well defined.
- Analysis of the aquifer material in the eastern and central hotspots, at the same depth as the water samples were drawn, yielded VOC concentrations of 25,000 ppb (location TCE-8) and 139,000 ppb (location TCE-15).
- The western hotspot (centered around location TCE-37) is the only ground-water sample in which TCE was not detected (but high concentrations of other VOCs were). It is located just 40 feet east of a former settling pond and is less than 60 feet from



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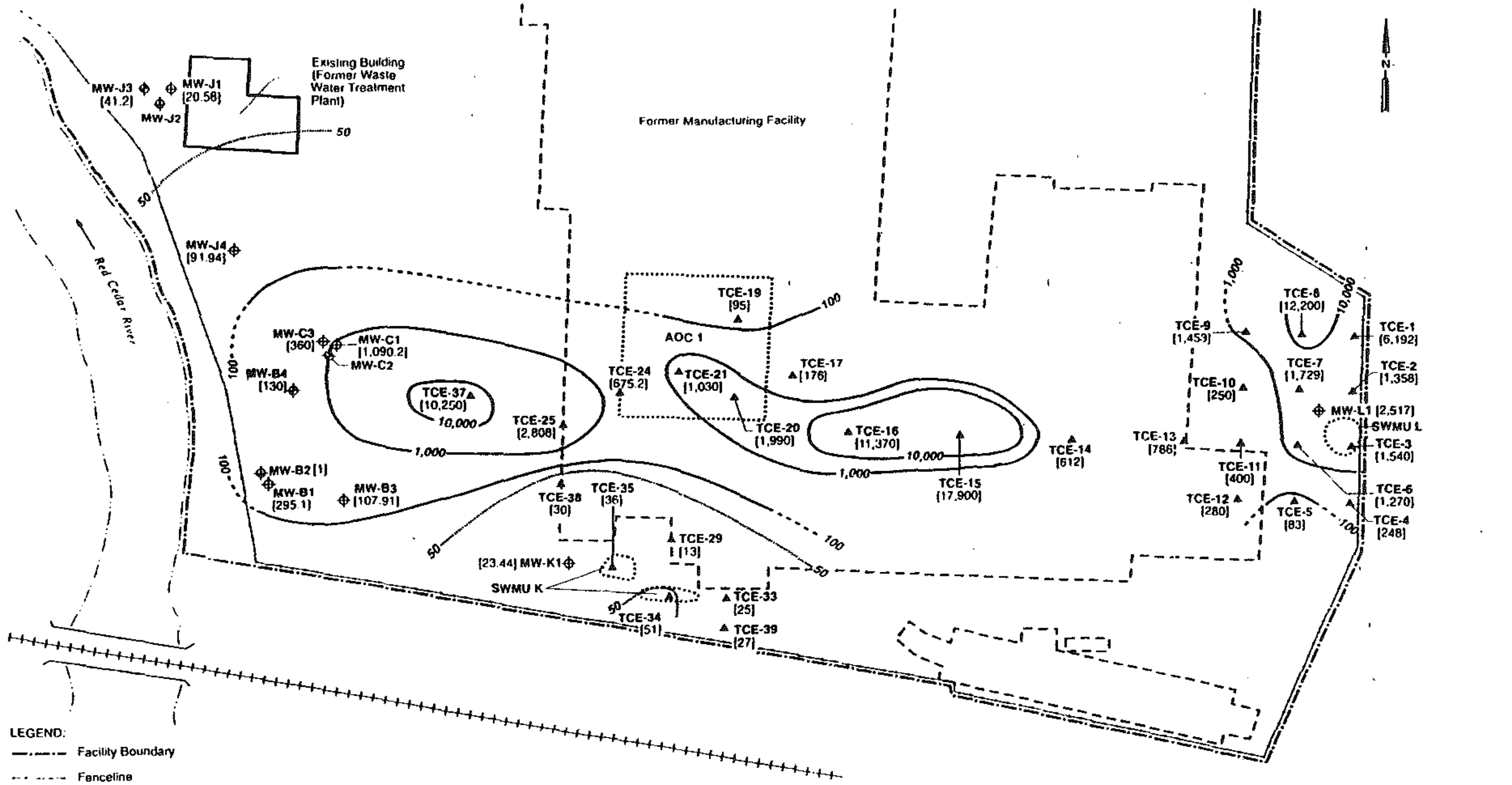
RIVER SAMPLING LOCATIONS AT THE JOHNSON CONTROL SITE

FIGURE 3



LEGEND:

- Facility Boundary
- Fenceline
- Railroad Track
- Former Building Location
- Solid Waste Management Unit/Area Of Concern Location (See Figure 4-3 for SWMU Description)
- ▲ Soil Boring Location
- Shallow Monitoring Well Location
- Intermediate Monitoring Well Location
- Deep Monitoring Well Location
- [295.1] Total VOC Concentration in Groundwater Sample (µg/L)
- 100 VOC Concentration Contour (µg/L) (Dashed Where Inferred) (Intermediate Value Contour Dotted)

0 40 80

APPROXIMATE SCALE IN FEET

BASE MAP SOURCE. Modified from Advanced Mapping Technologies compiled by photogrammetric methods from aerial photograph dated November 8, 1990

Adapted from Phase III RFI report.

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JCI'S TCE PLUME INTERPRETATION

FIGURE 4

monitoring well MW-C1 where kerosene was found floating on the water table. Water from TCE-25, located just 40 feet east of TCE-37, contained trace levels of xylene and isopropyl benzene, both petroleum product constituents.

- Ground-water sampling points TCE-37 and TCE-25 stood out from all others in that they contained vinyl chloride concentrations approximately one to two orders of magnitude higher than any other sampling point, and the vinyl chloride/TCE ratios were significantly higher than elsewhere.

Some conclusions that can be drawn from these observations are discussed in the following sections.

4.2 TCE degradation at the site

Trichloroethylene degrades in the environment by sequential removal of chlorine atoms, a process known as reductive dehalogenation, when conditions are reducing (oxygen poor). This anaerobic degradation creates a series of daughter products in the water: dichloroethylene (DCE), vinyl chloride (which is more toxic than TCE), carbon dioxide and water. The concentration ratios among TCE and its daughter products depend on how much of the TCE has been degraded and on the relative speeds of the subsequent reaction steps. The factors that control the rates of the degradation reactions are not fully understood, but bacteria and certain metallic elements in the aquifer often play important roles. Since most shallow aquifers are oxygen rich, hence not reducing, TCE often persists for extended time periods in the ground water without significantly degrading.

The relation between degradation and oxygen is the opposite for petroleum products such as kerosene. These are biologically degraded by bacteria which continuously consume oxygen to sustain the reaction. Thus, the biodegradation of petroleum products often depletes dissolved oxygen in the ground water and promotes a reducing environment. In shallow aquifers, where the presence of oxygen ordinarily inhibits TCE breakdown, active degradation of petroleum can give rise to anaerobic, reducing conditions under which TCE breaks down.

It is clear that TCE is being degraded at the JCI site, but the reaction is not going to completion. Virtually all sampling locations along the plume still contained TCE and significant concentrations of DCE and vinyl chloride. The ratios among TCE and its daughter products along the length of the plume strongly suggest that degradation of petroleum products is important at this site in controlling degradation of chlorinated compounds. For example, the areas in which the highest levels of vinyl chloride are present are in the vicinity of units which involved petroleum. Location TCE-37 is particularly significant because it had extremely high concentrations of the TCE breakdown products vinyl chloride (1700 ppb) and DCE (8,370 ppb), but TCE itself was absent. This might be explained by TCE-37's location immediately adjacent to wells which contain kerosene (possibly originating from operations related to the former settling ponds).

Past and present conditions are not a very good guide to future conditions because the changing petroleum concentrations in the subsurface may ultimately control the degree and duration of chlorinated solvent degradation. If the biodegradable constituents of the kerosene are exhausted or removed by remediation of relevant SWMUs, but TCE source areas are not controlled, then degradation will decrease.

4.3 Problems with JCI's plume interpretation

The conclusions section of the Phase III report concedes that there are data gaps relating to the TCE plume in ground water but argues (p. 6-9) that "TCE impact diminishes in off-site directions and is not expected to persist at significant concentrations because of its demonstrated attenuation away from source areas." This conclusion is not supported by the data:

- The contaminant plume does not display "demonstrated attenuation away from the source area." The plume is continuous across the site, with maximum VOC concentrations roughly the same in the eastern (12,200 ppb), central (17,900 ppb), and western (10,250 ppb) portions of the plume. JCI's depiction of the plume as three distinct hotspots is not sufficiently justified by the data. For example, there are no data points to justify the closed concentration contours drawn north of TCE-15 and west of TCE-9.

- Johnson Controls drew Figure 5-3 of the Phase III RFI report (our Figure 3) in a way that suggests that little VOC contamination reaches the river. This is misleading. Wells as close as 50 feet from the river contain hundreds of ppb of VOCs, including vinyl chloride. There is little support for drawing, even tentatively, a 100 ppb concentration contour in front of the river.

- Although it is true that TCE is degrading along portions of the plume, the process has not gone to completion. TCE and its daughter products remain in all sectors of the plume. For example, monitoring well MW-C1, which is approximately 60 feet from the river, contained 700 ppb TCE. Even at sampling location TCE-37, where TCE degradation appears to be most advanced because no TCE was detected, there is still 8,370 ppb of DCE and 1700 ppb of vinyl chloride.

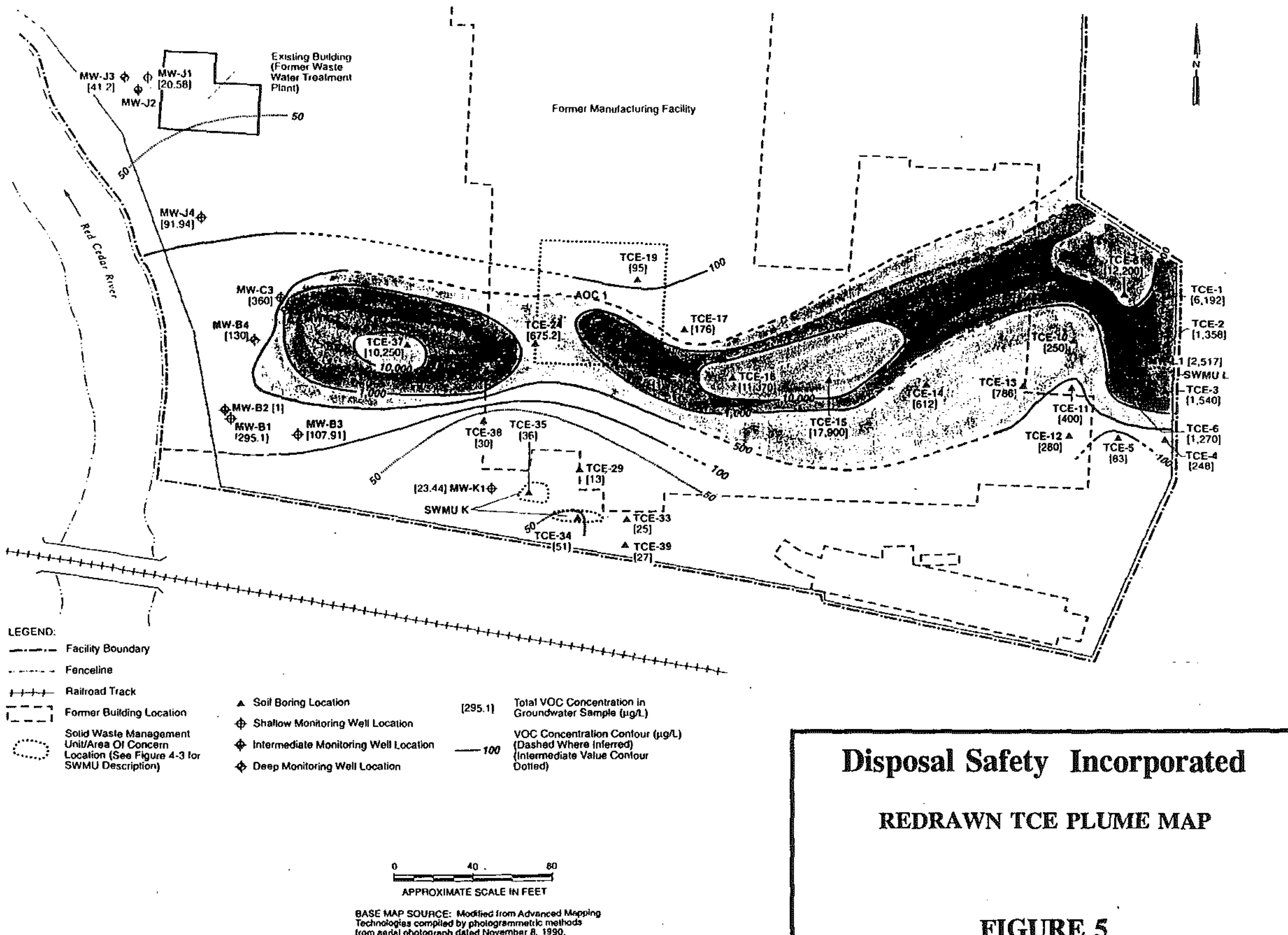
- The daughter products are also quite toxic. The Phase III report listed USEPA's generic clean-up criteria for TCE, cis- and trans-dichloroethylene, and vinyl chloride as 5 ppb, 70 ppb, 100 ppb, and 2 ppb, respectively. These criteria are exceeded in all portions of the plume.

In Figure 5 we have redrawn JCI's plume map in a way that we believe better conforms to the chemical and hydraulic data. We have opened the 1000 ppb contour north of TCE-9 and TCE-15, and extended the 100 ppb contour to the river.

Although both the Phase III Report and the Summary Report repeat the claim made in Phase II that TCE contamination is entering the JCI facility from an off-site source to the east, the Summary Report tempers this assertion with a discussion of the far more likely scenario in which the contamination resulted from degreasing and other operations at the site. In this latter scenario, the hotspots represent areas of significant releases.

The Phase III ground water investigation data gives us a much better picture of the plume, but it is not yet complete. There are not enough deep wells to determine the presence or absence of deeper migration and the current data set does not yet identify a specific source of the TCE with any confidence. In particular, there is still nothing to support JCI's claim of an off-site source possibly caused by some other party.

It is not clear what JCI means by its assertion that TCE impact "diminishes in the off-site directions." The plume is moving in only one direction, west, and at least partly discharging into the river. As discussed above, the concentrations have not demonstrated much attenuation when the daughter products are also considered. The issue that needs to be addressed is the effect of a largely unattenuated plume either discharging into the river, or possibly migrating under it.



Disposal Safety Incorporated

REDRAWN TCE PLUME MAP

FIGURE 5

JCI defined its second screening criterion as the 95% upper confidence limit of the maximum background concentration for each chemical species. This is a calculated value which should exceed the values measured in 95% of all background samples. The method used by JCI to calculate the confidence limits assumes that the sample concentrations for each chemical follow a normal distribution (bell shaped curve) and that enough samples were collected to fully describe the distribution.

The 95% upper confidence limits in the Phase III report were determined by statistically analyzing a relatively small number of upstream samples — eleven. Seven of these samples were collected in Phase II and only four in Phase III. This is not sufficient to develop robust statistics.

Furthermore, the conceptual basis for JCI's comparison of upstream samples to downstream samples is flawed. The rationale for using statistics is that there should be two statistically distinct populations if the site has contaminated the river. The best way to evaluate the degree of contamination is to fully analyze and compare the two complete sets of data. JCI did not do this. Instead, JCI compared individual downstream samples, one at a time, to the background range to reduce the number that could be blamed on the site.[2] Good methods do exist to distinguish background concentrations from site contamination [Magee et al., 1990], but they require a sufficient number of background samples and the use of appropriate techniques of analysis. Magee et al. recommend a more complete statistical analysis of background and site related samples to facilitate the development of meaningful screening criteria.

Johnson Controls did recognize one problem with the analysis. It found that many of the *upstream* concentrations exceeded the calculated confidence limits. In other words, there were non-normal statistical distributions of the contaminants. This may be true. But this may not represent a fundamental characteristic of the samples themselves. As discussed below, the non-

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[2]Comparing a single measurement to the 95% confidence limit of the background data set answers the question: "Could this sample have been found if there was no site contamination?" The proper question is: "Do the data as a group indicate that the site is or is not contaminating the river?" To answer this question, sample populations must be compared to each other, and the data must be searched for temporal and spatial trends that could be hidden by statistical analyses that lump together data collected at different times and places.

normal distribution may have arisen from improperly grouping old and recent data (which would combine two distinct populations).

Because concentrations in many of the upstream river samples exceeded the 95% upper confidence limit, JCI dismissed these screening criteria as "likely to be overly conservative" and argued for yet a third criteria to distinguish site contamination: the maximum measured upstream value for each potential contaminant. This value is, of course, distinctly non-conservative because it ignores the fact that sampling always yields distributions of concentrations, and distinct distributions frequently overlap. Thus, site contamination may have significantly elevated the mean concentrations of samples, but elevated individual samples may still fall below the maximum values measured in the background samples.

The way JCI calculated its maximum upstream concentration screening values is troubling in another way. The Phase III report states that, in general, concentrations in the river were lower during phase III (2000) than in Phase II (1994), thus the "Phase II data may no longer adequately characterize site conditions." JCI states that this justified using the Phase II data "only for characterization of upstream conditions" (page 6-8); that is, all other values used in the screening analysis were collected in Phase III. But comparison between the Phase II and Phase III data shows that upgradient contaminant levels have decreased in the subsequent six years, as would be expected if there was progress in cleaning up the river upstream of the plant. This means that the maximum upstream concentrations, which JCI argues are indicative of background, are based on a data set which may be incompatible with the downstream data, at least for the purposes of apportioning contamination currently attributable to the JCI site. For example, the maximum upstream values in Phases II and III were 35.8 and 11.1 ppm for arsenic and 12.3 and 6.7 ppm for chromium, respectively. Clearly, it makes the most sense to use measures of current background when evaluating the current and future impact of the site on the river.

5.2 Impact of the site on the river

The Phase III RFI seems to conclude that there is little present day impact on the Red Cedar River from the site. Exceedences of screening values are generally cited without comment, or dismissed as either "very limited" or within background concentrations. For example, even when chromium was found in the river sediment adjacent to the facility at concentrations that exceeded the maximum measured upstream, the Phase III RFI report argues that it could "easily fall within the statistical distribution of background (given the non-normal distribution of the upstream data)" (p. 6-7). JCI also points to the municipal treatment plant outfall, and other things downstream, as possible sources of chemicals in the river.

Although we did not perform a statistical analysis of the data (and we question whether sufficient upstream data exists to perform one), we did calculate mean concentrations for PCB and chromium. These are listed in Table 3. The mean concentrations strongly indicate that releases from the JCI site have elevated PCB and chromium concentrations in the sediment.

Table 3

Comparison of Upstream and Downstream Mean Concentrations

Chemical	Mean Concentration of Samples (ppm)					
	Upstream of JCI		South Ditch	River Adjacent to JCI Site	River Downstream of JCI	River North of Sewage Treatment Plant
	Phase II and Phase III Data	Phase III Data				
Total PCB	Not detected	Not detected	3.4	0.040	0.040	0.020
Chromium	7.5	5.8	471.0	11.7	48.0	27.1

Another issue not addressed by the RFI concerns PCBs. On site, PCBs have been found in the subsurface dissolved in the floating kerosene phase. PCBs in the subsurface are ordinarily quite immobile, due to their low solubility and tendency to adsorb on soil particles. However, PCBs would move with the kerosene and could migrate into the river dissolved in the non-aqueous phase. Upon entering the river, PCBs dissolved in oil droplets would be much more likely to remain in the water column than PCBs in a water-sediment system. This could make them more bioavailable. Default risk assessment assumptions for PCBs in streams are based on a water-sediment system, and would not be applicable to PCBs dissolved in oil.

5.3 The South Ditch

Sediment samples from the South Ditch contained levels of PCBs, chromium, arsenic, cyanide, and mercury that exceeded EPA screening levels and JCI's as well. PCBs were found in four of five samples, with concentrations as high as 13 ppm; this is more than 100 times all three of JCI's screening levels. The ditch samples contained chromium as high as 955 ppm; this is 35 to 100 times JCI's screening levels. We note that although JCI compared contaminant concentration in the ditch to screening levels it developed from upstream river sediment, this is not useful for distinguishing contaminant origin. Unless it can be shown that the sediments in the South Ditch were predominantly deposited by flooding of the Red Cedar River, levels of chemicals in the ditch would have little relation to those in the upstream portion of the river.

6. Site-wide contamination

The Summary Report includes a great deal of information that is repeated from the three earlier RFI reports. It does add, however, a more detailed analysis of site-wide soil and ground-water contamination.

6.1 Soil

Phase I and Phase II soil contamination data are compared to Preliminary Remediation Goals set by USEPA Region 9 (California, Nevada, Hawaii, and Arizona). Figures 6-1 through 6-7 of the Summary Report show that soils covering much of the site exceed USEPA criteria for protection of ground water or for residential and industrial exposure to arsenic, chromium, and PCBs.

The Summary Report questions the significance of these exceedances, however, arguing that for arsenic, and to some extent chromium as well, background levels in the soil exceed the clean-up criteria. Johnson Controls asserts misleadingly on p. 6-6 of the report that most arsenic concentrations "are of a similar magnitude to the site-specific background values reported in Tables 5-24 and 5-25."

This statement about arsenic is misleading for several reasons. First of all, the values given in the tables are not supposed to be typical background concentrations, but are intended to be three standard deviations above the mean, and therefore should exceed 99% of all background concentrations. The highest such limit suggested anywhere in JCI's background table is 44.9 ppm, while concentrations over 60 ppm were measured in the soil and nearly 70 ppm was measured in the sediment of an abandoned pipe beneath the site. The arsenic in samples that exceed the calculated background limits is *not* background arsenic, notwithstanding that they are "of a similar magnitude" to one of the calculated limits.

Second, the background limits are not correct. JCI, claiming to follow MDEQ guidance, defines background values for each chemical as the mean concentration plus three standard deviations measured in on-site soil that is presumably uncontaminated. In the case of arsenic, JCI calculated the unusually high value of 44.9 ppm as the background concentration for the upper three feet of soil. There are several problems with JCI's calculation:

- JCI's background values are based on samples from only four locations. These are too few samples to generate reliable statistics when the coefficient of variation is large, which is the case for arsenic.

- The coefficient of variation for arsenic in the upper three feet of soil was 0.84. MDEQ guidance [MDEQ, 1994, p. 16] states that the three standard deviation method may only be used with a large coefficent of variation (greater than 0.75 for clayey soils) if a valid explanation is presented; otherwise another statistical method must be used.

- The geology across the site is quite variable, both horizontally and vertically. MDEQ guidance requires that background concentrations be calculated for each distinct stratigraphic horizon. This is important because clay has the highest background arsenic content of all soil types while arsenic concentrations are typically much lower in sand and other kinds of soil. All background samples were collected from a single, limited, area on-site where a few feet of clay overlie a sandy layer. Johnson Controls calculated a shallow background arsenic value (44.9 ppm, 0 to 3 feet below the surface) and a deeper one (3.4 ppm, 3 to 7 feet below the surface). Even if these values were correctly calculated, their use would not be proper; as MDEQ guidance states, background values should not be determined for depth intervals without distinguishing among soil types.

A further indication that there is something wrong with the JCI's value of 44.9 ppm for shallow background soil is how it compares with the values for arsenic in the Michigan Background Soil Survey [MDNR, 1991]. The maximum background arsenic value found in this state-wide survey of 311 samples was 39.0 ppm. The survey was subdivided by soil type and geographic category. Out of 178 clay samples, the mean, the mean plus three standard deviations, and the maximum concentration were 8.8, 34.3, and 39 ppm, respectively. The mean, mean plus three standard deviations, and maximum of the 75 clay samples from Fowlerville's geographic category (the Saginaw glacial lobe) were 6.3, 27, and 30.6 ppm, respectively. JCI's proposed background of 44.9 ppm exceeds every measurement of arsenic background reported by the survey anywhere in the state, an extremely unlikely occurrence if it were accurate.

6.2 Ground water

Concentrations of chemicals in the ground water were compared with three screening criteria: Michigan Part 201 generic clean-up criteria for ground water at industrial and commercial sites, USEPA Region 9 preliminary remediation goals for tap water, and Federal maximum contaminant levels for drinking water. Figures 6-8 through 6-13 of the Summary Report show that significant portions of the site exceed these standards for one or more of four contaminants: arsenic, TCE, vinyl chloride, and cyanide.

The Summary Report states that Michigan Part 201 generic clean-up criteria and screening levels for industrial-commercial scenarios are "not available" for arsenic, chromium, TCE, and PCBs. But such values are in fact available. Pages 6.3, 6.4, and 6.7 of MDEQ's Op Memo 18 give the values:

7. Conclusions and recommendations

It is now more than twenty years since ground-water contamination was discovered beneath the Johnson Controls site in Fowlerville and PCBs were discovered in the Red Cedar River. Yet no remedy has yet been selected, let alone implemented. The pollution problem has not even been fully investigated — the horizontal and vertical extent of ground-water contamination has not been fully determined, and clean-up goals for the river sediment have not yet been set. Our evaluation shows serious deficiencies in the work done to date, and even JCI admits that there are still "limited data gaps" [p. 6-9 of the Phase III RFI report].

Once the investigation has been completed, the next step in the RCRA corrective action process is Corrective Measures. JCI is in the process of negotiating a new Consent Order with USEPA so it can begin a Corrective Measures Study (CMS). Under this regulatory approach, any additional investigation will be tied to whichever specific remedies are required by USEPA after it reviews JCI's CMS.

The data gaps we have identified are more severe than admitted by JCI. Furthermore, the existing data have yet to be fully or appropriately analyzed. Nevertheless, we agree that there are sufficient data to begin to consider different remedial options. Although more detail than is appropriate for this report will be required to fully evaluate clean-up requirements, we believe that the data lead to several basic conclusions, which are discussed below.

7.1 TCE plume

Data from the RFI investigation clearly shows that there is a continuous plume of solvent-contaminated ground water discharging into the Red Cedar River. More work will be needed to determine TCE source areas and the depth of the VOC plume. Additional permanent wells are recommended both on site, along the length of the plume, and off site east of the plant boundary and on the west side of the river. Several of these will need to be deep zone wells.

Under present conditions it is clear that natural attenuation[3] does not fully degrade the plume before it discharges into the river or, possibly, flows under it. Therefore, natural attenuation is not viable as a stand-alone remedy at the JCI site. Furthermore, on-going clean-up of the oily wastes and sludges at the site will tend to remove the oxygen sink; thus the degree of natural attenuation attributable to biodegradation could decrease in the future. At the very least, a much more comprehensive understanding of ground-water chemistry and TCE fate processes is required before natural attenuation can be considered even as a component of an engineered remedy. The National Academy of Sciences' Committee on Intrinsic Remediation [National Research Council, 2000] recently published guidelines for such evaluations.

[3]Natural attenuation is defined as involving natural processes such as absorption, dilution, volatilization, chemical and biological degradation, etc. which remove or permanently immobilize contaminants in the subsurface. This is in contrast to engineered remedies such as ground-water pump-and-treat (ground water is pumped from the ground and cleaned), reactive barriers (ground water is directed to flow through a subsurface barrier that chemically destroys contaminants), and others.

After so many years of study, there is no reason for further delay before the VOC plume is contained. Several cost-effective methods, including well-based hydraulic containment and zero-valence treatment walls are available to do this. This site is well suited to these methods because the plume is relatively narrow and the aquifer transmissivities are modest. Pumping and treating ground-water hotspots can probably reduce the duration of containment, and would only require a few wells. If additional investigation identifies strong TCE source areas, then additional containment, treatment, or removal measures may be required.

7.2 River water and sediment quality

Past and recent investigations show that PCBs, metals, and other chemicals from the plant have contaminated the river and its sediments. JCI contends that the level of river and sediment contamination resulting from the JCI site has dropped over time. This may be true, but it is also clear that contaminant levels still exceed USEPA's Ecological Data Quality Levels, and that the JCI site continues to be a source for these exceedences.

Continued on-site clean-up of water, sludge, and contaminated soils associated with the known Solid Waste Management Units may facilitate further improvements in river quality over the long run. However, JCI's studies have identified pervasive site-wide soil contamination, and this too provides an ongoing source of contaminated water and sediment into the river. JCI needs to implement a comprehensive program to control all site-related discharges and run-off that could flow into the river. Controlling run-off into, and discharge from, the north and south ditches is central to this. Because ground water beneath most of the site contains elevated metals, including arsenic, ground-water discharges into the river may need to be controlled over a wider area than the TCE plume.

Because most of the site is situated on the flood plain of the Red Cedar River, remedial measures must be put into place to prevent contaminated soil from washing into the river during large-scale floods. This might include either excavation or capping of appropriate areas.

The extent to which remediation of river sediment is required is likely to depend on the results of a risk assessment. The National Academy of Sciences has described risk assessment as an "analytic-deliberative process" that requires representation of the spectrum of interested parties [National Research Council, 1996]. The Academy emphasizes that:

Of critical importance is maintaining the integrity of the analytic process; in particular, protecting it from political and other pressures that may attempt to influence findings or their characterization so as to bias outcomes.

As described throughout this report, studies carried out by JCI's consultants have shown a consistent bias in the direction of understating the degree of contamination. It is of great importance to avoid both the appearance and the reality of a biased risk assessment. For this reason, all risk assessments at this site should be conducted by USEPA staff.

In the risk assessment, special attention needs to be given to the possibility that PCBs are entering the river dissolved in kerosene. Because PCBs are hydrophobic, they ordinarily sorb strongly to sediment particles. PCBs dissolved in a liquid hydrocarbon phase would be less rapidly scavenged out of the water column and could be much more bioavailable.

7.3 Arsenic in soil

Arsenic concentrations in on-site soils are well above clean-up criteria. JCI has not correctly defined background levels, and therefore its suggestions that the arsenic may be background-related cannot be accepted. The arsenic problem requires further investigation to determine what kind of clean-up is necessary.

References

Kolesar, A. L., Letter to F. Gomez, USEPA Region 5 Office of Regional Counsel, re: Former Stanley Tools Site; Fowlerville, Michigan, dated March 19, 1996.

Magee, B. R., Schuyler, S. E., and C. Kufs, The use of background concentrations in site assessments," in *Ground Water Management: Proceedings of the 1990 Cluster of Conferences, Vol. I*, pp. 861-876, February 20-21, 1990, Kansas City.

MDEQ, *Guidance Document, Verification of Soil Remediation*, Revision 1, Michigan Dept. of Environmental Quality, Environmental Response Division and Waste Management Division, April, 1994.

MDNR, *Michigan Background Soil Survey*, Michigan Department of Natural Resources Waste Management Division, April, 1991.

National Research Council, *Understanding Risk*, National Academy Press, Washington, 1996, p. 158.

National Research Council, *Natural Attenuation for Groundwater Remediation*, National Academy Press, Washington, 2000.

Appendix A

LIST OF PREVIOUS REPORTS ON THE STANLEY TOOLS SITE.

From the draft *Phase II RCRA Facility Investigation Task 10* report,
Dames & Moore, 1994.

TABLE 3-1

LIST OF PREVIOUS REPORTS

STANLEY TOOLS
FOWLERVILLE, MICHIGAN

Report Title	Agency/Author	Date of Report
Utilex Corporation, Fowlerville, Michigan, March 27 and 28, 1956, Wastewater Survey.	MWRC, E. Shannon	Not dated
Report on Biological Conditions and Water Quality of the Red Cedar River as Affected by Discharges from the Hoover Ball and Bearing Company, Utilex Division, Fowlerville, Michigan. 1953-1967.	MDNR, R. B. Willson	Not dated
Report on Biological Conditions of the Red Cedar River as Affected by Discharges from the Hoover Ball and Bearing Company, Utilex Division, Fowlerville, Michigan.	MDNR, George Jackson	10/19/71
Biological Studies on the Toxicity and Biomagnification of Metals, Hoover Ball and Bearing Company, Utilex Division, Effluent and Red Cedar River, Fowlerville, Michigan.	MDNR, Mark Wuerthele	1/4/72
Michigan State University, masters thesis. Subject: To determine the effectiveness of new treatment facilities installed at a metal plating plant on a warm water stream (Red Cedar River).	Unknown	6/74
Compliance Monitoring Report, Hoover Ball and Bearing Company, Utilex Division, Fowlerville, Michigan, NPDES Permit MI 0003727.	U.S. EPA, Robert Buckley	7/74
Report of an Industrial Wastewater Survey Conducted at Hoover Ball and Bearing Company, Utilex Division, Livingston County, Fowlerville, Michigan, June 10-12, 1974.	MDNR, Bradley Brogren	8/12/74
Report of an On-Site, Continuous-Flow Bioassay Conducted at Hoover Ball & Bearing Company, Utilex Division and a Water Quality Study Conducted on the Receiving Waters Below the Plant Discharge, Livingston County, Fowlerville, Michigan, June 10-14, 1974.	MDNR	5/19/75
Report of an Industrial Wastewater Survey Conducted at Hoover Ball and Bearing, Utilex Division, All Outfalls No. 470003, Livingston County, Fowlerville, Michigan, June 23-24, 1975.	MDNR, Richard Christensen and Sidney Beckwith	8/7/75

TABLE 3-1 (Continued)

Report Title	Agency/Author	Date of Report
Report of an On-Site, Continuous-Flow Bioassay Conducted at Hoover Ball and Bearing Company, Utilex Division (Outfall 470011-001), Livingston County, Fowlerville, Michigan, May 24-28, 1976.	MDNR, Gerald Saalfeld	7/13/76
Report of an Industrial Wastewater Survey Conducted at Hoover Ball & Bearing Company, Utilex Division, All Outfalls No. 470003, Livingston County, Fowlerville, Michigan, May 24-26, 1976.	MDNR	7/15/76
Report of an Industrial Wastewater Survey Conducted at Hoover Ball & Bearing Company, Utilex Division, All Outfalls No. 470003, Livingston County, Fowlerville, Michigan, September 13-14, 1977.	MDNR, Roger Lemunyon	11/2/77
Water Quality and Biological Investigation of the Red Cedar River in the Vicinity of the Hoover Universal Die Cast Co., Fowlerville, Michigan, September 9, 1976 and January 24, 1978	MDNR, Susan Sylvester	6/78
Report of a Toxicity Evaluation & Industrial Wastewater Survey Conducted at the Hoover Universal, Utilex Division, All Outfall 470003, Livingston County, Fowlerville, Michigan, May 22-26, 1978.	MDNR	7/6/78
Letter from MDNR to Hoover Universal Corporation listing results of samples collected July 13, 1978.	MDNR, John Kraft	8/1/78
Biological Investigation of the Red Cedar River in the Vicinity of the Hoover Universal-Utilex Division, Fowlerville, Michigan, Livingston County, July 10, 1978-August 22, 1978.	MDNR, Gerald Saalfeld	6/10/79
Report of Daphnia Toxicity Screening Tests Conducted with Wastewaters from Hoover Universal - Utilex Division, All Outfall 470003, Livingston County, Fowlerville, Michigan, May 15, 1979 (Appendix A).	MDNR, Ronald Waybrant	7/26/79
Report of an Industrial Wastewater Survey Conducted at Hoover-Universal, Inc., Die Casting Division, All Outfalls No. 470003, Livingston County, Fowlerville, Michigan, May 15-16, 1979.	MDNR	7/30/79

TABLE 3-1 (Continued)

Report Title	Agency/Author	Date of Report
Report of an Industrial Wastewater Survey Conducted at Stanley Tools (formerly Hoover Universal), All Outfalls No. 470003, Livingston County, Fowlerville, Michigan, January 22-23, 1980.	MDNR, Martin Beck and Joseph Hey	3/25/80
Compliance Sampling Inspection for Stanley Tool, Fowlerville Plant, MI0003727, conducted by U.S. EPA Eastern District Office on September 22, 1980.	U.S. EPA	7/6/81
Report of an Industrial Wastewater Survey Conducted at Stanley Tool Company, All Outfalls No. 470003, NPDES Permit No. MI0003727, Livingston County, Fowlerville, Michigan, March 29-30, 1982.	MDNR, Peter Ostlund and Edward Hamilton	5/20/82
Report on an On-Site Toxicity Evaluation at Stanley Tool Company, Facility No. 470003, NPDES Permit No. MI0003727, Livingston County, Fowlerville, Michigan, October 4-8, 1982.	MDNR, William Erickson	3/83
Report of an Industrial Wastewater Survey Conducted at Stanley Tool Company, All Outfalls No. 470003, NPDES Permit No. MI0003727, Livingston County, Fowlerville, Michigan, October 5-6, 1982.	MDNR, Ralph Reznick and Joseph Hey	12/28/82
Quarterly Results (10/83) Groundwater Quality Assessment Program Stanley Tools, Fowlerville, Michigan.	Keck Consulting Services, Inc.	2/3/84
Quarterly Results (1/84) Groundwater Quality Assessment Program Stanley Tools, Fowlerville, Michigan.	Keck Consulting Services, Inc.	4/3/84
March 1984 Ground Water Assessment Report, Stanley Tools Plant, Fowlerville, Michigan.	Environ Corporation	2/27/85
Response to Comments on the March 1985 Groundwater Assessment Report.	Environ Corporation	3/21/86
Final Report, Ground Water Quality Assessment, Stanley Tools Plant, Fowlerville, Michigan.	Dames & Moore	7/10/87
A Biological Survey of the Red Cedar River, Livingston and Ingham Counties, Michigan (6/24-28/91).	MDNR, Staff Report	1/92